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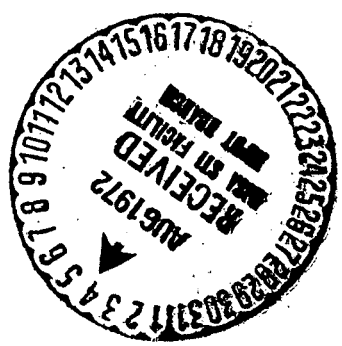

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SPACE TRANSPORT VEHICLE:
PURPOSE, REQUIREMENTS AND PROBLEMS *

V. Vasil'yev and L. Leonidov

The flights of Soviet and American Astronauts during the past 11 years have demonstrated that the presence of a man on board a spacecraft considerably expands the potential of rocket and space technology, increases its reliability and work capacity, and permits the effective fulfillment of large and complex programs. In the next decade, one can expect a further increase in the role of manned space flights and inhabited space apparatus. The creation of long-duration orbital stations in near-earth and near-lunar orbits and the preparation for interplanetary expeditions require the delivery of large payloads into space as well as astronauts for crew replacement. Specialists propose frequent shuttle operations, that is, flights between near-earth and near-lunar orbital stations. This is essential to supply all of the necessities for long-duration orbital stations, base-stations on the lunar surface and for interplanetary flights.

Space objects (manned and unmanned) are still being inserted into orbit by booster rockets used once. Manned spacecraft are also rated for a single launch. In addition to this, from the point of view of prospective requirements, they possess low maneuverability and can be landed only by parachutes.

Nevertheless, such manned orbital apparatus and the means for their launch satisfy and will continue to satisfy the requirements presented to rocket and space technology. But with an increase in the rate of launchings of space objects, particularly manned, the technology of one-time use becomes economically unsuitable. Additionally, other not inconsiderable deficiences are inherit in the one-time system. In particular, booster rockets do not provide all-azimuth launchings, foreign territories are required for the landing of the spent rocket stages, and considerable time is consumed in preparation for launching.

The descent manned apparatus of rocket and space systems, owing to their low lift-drag ratio (K=0-0.5), rely upon ballistic or glide descent into the dense layers of the atmosphere with considerable overloads (G - force) This presents high requirements for stability of the spacecraft design and for their heat shielding. Also, large overloads are unacceptable for astronauts undergoing long periods in weightlessness.

In connection with the parachute landing of such apparatus, special means of search and evacuation of the landed apparatus and astronauts from the landing region, as well as additional alien territories on which their ground landing can occur, are necessary.

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* Based on foreign press information

All of this explains the need to create basically new space systems free of the deficiences cited and being capable of many-time use.

The possibility of creating space flight apparatus capable of flying in the atmosphere, of entering near-earth orbit and completing a landing like an airplane at its own airport, has been studied for a long time. In the U.S.A., for example, a large number of studies which include flight experiments has been conducted on orbital flying spacecraft of the flying body type which possess a lift-drag ratio of 1.0-1.3 at hypersonic speeds and up to 3.0-3.5 at subsonic speeds which makes it possible to land them like an airplane after descent from orbit over a given territory.

On January 5, 1972, the President of the U.S.A. decided to create a transport vehicle capable of repeated use. In accordance with this decision, a program of its development is being considered the chief element of the national space program. Such great attention, being paid to the development of a transport vehicle, the American specialists explain by the fact that the expected cost of inserting a unit weight of payload into orbit with its assistance should be considerably less than during insertion by the usual booster rockets. (The insertion into orbit of one kilogram of useful payload now amounts to $1,330 - $1,550, but with the creation of a vehicle as proposed by NASA specialists, it is reduced to $220.)

Officially, the program to develop a transport vehicle is connected with the provision of flights of a long-term orbital station capable of holding 12 men whose launching is planned for 1977-1978. The U.S.A. is pursuing this program both for scientific as well as for military purposes.

Transport vehicles can insert into orbit different loads including satellites for scientific, commercial and military purposes, booster rocket and orbital stage units for subsequent assembly in orbit, as well as for the return to earth of expensive space objects which have malfunctioned but still can be re-used.

The transport vehicles are considered as means for the emergency rescue of crews from long-duration orbital stations and other apparatus which suffer an emergency in orbit.

The requirement has been introduced that the payloads placed in orbit by the transport spacecraft amount to around 30 tons. This is conditional on its design, dimensions, and type of launch. The vehicle is considered for long-term exploitation (not less than 100 flights in the course of ten years).

The preliminary developments have shown that the most prospective scheme for a re-useable heavy transport vehicle is a two-stage vehicle using a booster stage (an aircraft-booster or a booster rocket) and of an orbital apparatus containing the crew. The launching would be vertical.

At the present time, the firms requested to create such transport vehicles, have basically completed the preliminary design stage and are conducting work on the complete evaluation and comparison of preliminary projects.

The appearance of the orbital stage of the transport vehicle is more readily determinable. This is a winged flying apparatus (possibly the use of a wing with a variable geometry) capable of maneuvering laterally within the limits of 2000 kilometers and of landing like an airplane at a typical airport. Its maximum lift-drag ratio hypothetically is 1.1-13. at hypersonic speeds and 3.1-3.5 at subsonic speeds of the orbital stage with two crew members on board who must be capable of inserting around 29.5 tons of loads into a 400-500 kilometer orbit or a 12-man crew with its initial weight of about 300 tons. To do this, a load compartment with a volume of 200-300 cubic meters is provided. The flight duration is up to 7 days, however, without passengers, up to 30 days. The orbital stage should possess the potential for maneuvering in orbit and to change its altitude and orbital plane. The overloads during descent into the dense layers of the atmosphere should not exceed two.

The power plant of the orbital stage will consist of liquid rocket engine boosters with variable thrust operating on hydrogen and oxygen, low thrust engines for orientation and stabilization of the apparatus in outer space and possible air-jet engines to provide safe landings at an airport and subsequent ferrying of the orbital stage to the site of the next launch.

To study the optimal variants of the arrangements for an orbital stage, the results of the flight test of the experimental aircraft, M2-F2, HL-10 and X-24A, conducted according to the "START" program, were used.

In the initial stage of the design of the first stage, an aircraft-booster with vertical launch was provided, equipped with 8-10 liquid rocket engines using liquid hydrogen and oxygen and also with an auxiliary landing jet engines. The carrier should be capable of inserting the orbital stage into a circular orbit of 500 kilometers with an inclination of 55 degrees, or into a circular orbit at an altitude of 185 kilometers with an inclination of 28.5 degrees or into a polar circular orbit. After insertion of the orbital stage, its return to the takeoff base was provided. In this variant the launch weight of the multiple-use transport vehicle was estimated to be 1800-2200 tons.

However, more recently the possibility of using as the first stage of a transport vehicle the existing liquid-fuel and solid-fuel booster rocket with a parachute descent system has been studied. Thus it becomes a task of the repeated use of a rocket insertion system. This variation of a multiple-use transport spacecraft is an intermediate one since it still does not offer the possibility of avoiding all the deficiences

inherent in rocket launching. However, it does permit accomplishing the first launchings of an orbital stage in a shorter period of time and with fewer losses. In the second stage of creating a transport spacecraft, in the opinion of foreign specialists, one can expect the use of a booster stage of the aircraft type.

The general arrangement of the total system of transport spacecraft has still not been finally decided. A number of firms perfer an arrangement with successive positioning of the stages (as in the usual multi-stage booster rockets) which permits the use of the readily available design experience. However, the launching weight of a similar system is increased in comparison with the variation provided for by the parallel positioning of the stages. Consequently, the arrangement in the parallel stage position is more prospective.

As has been reported, the transport spacecraft is designated for use in military affairs. Which ones? These are identification, inspection and capture of the space objects of a potential enemy, completion of photo and radiotechnical reconnaissance, cartographic surveying, meterological surveying, target indication and delivery of information from reconnaissance satellites. This is confirmed especially from the data on the orbital parameters in which the transport spacecraft must be inserted. The orbits are characteristic for the American reconnaissance satellites.

However, it should be noted that to solve military problems in outer space, in the U.S.A. it was more expedient to study a spacecraft that is smaller, more maneuverable and having a fewer number of orbits (short lifetime) than the re-useable transport spacecraft being developed. At the end of the 1970s the idea of a short lifetime but highly maneuverable air-space aircraft with a horizontal launching which offered the possibility of rapid takeoff was intensively studied in the U.S.A. but could not be practicably solved. At the present time, the interests of the military and civilian administration have been combined in the heavy re-useable transport spacecraft which is being developed under the leadership of NASA but with the participation of the military.

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The development of the multiple re-use manned transport spacecraft is a very complex task associated with the solution a number of scientific and technical problems. One of these difficult-to-solve problems is the heat protection of the orbital stage during re-entry into the dense layers of the atmosphere. The need arises for the development of new methods of heat protection and new heat-protecting materials including active systems with cooling agents, heat protection by means of radiation, complex systems combining the use of ablative materials and materials with large radiative capacity, and for the search for new refractory and composite materials.

No less important is the problem of stability and control of the orbital stage during descent and landing.

The advantage of orbital stages having a lift-drag ratio larger than 0.5 is their capability to lower the overloads in a descent to acceptable values as well as to change comparatively easily the trajectory of motion in a lateral direction and thereby to maneuver to an airport landing.

However, the active use of the aerodynamic forces complicates the problems of stability and control exceedingly and leads to the need for using aerodynamic control units.

It has been stressed in the literature: the orbital stage in any case should be equipped with a reactive control system to maneuver in space. In this connection, it is very attractive to use reactive nozzles in the descent process in place of aerodynamic control.

Significant difficulties are associated with the creation of the engines for both stages of the transport spacecraft. As has been noted, engines using liquid hydrogen and oxygen in a high-pressure combustion chamber (190-210 atmospheres) are provided for the orbital stage, which must develop the necessary thrust with a high degree of its regulation. In accordance with the presented requirements, such engines should be relied upon for not less than 100 activations with a total operating life of up to 10 hours and for continuous operation of 10-60 seconds. For such engines, basically new design solutions are required on the arrangement of a liquid rocket engine, the fuel and oxidizer supply system, the turbine pump units, the combustion chambers, cooling systems, and placement of the fuel tanks, etc.

It should not be forgotten that the use of cryogenic fuel in turn is associated with the solution of many technical problems such as the storage of fuel, fueling, and the heat protection of the fuel tanks.

There has been considered the complex development of low-thrust engines with a large operational reserve for the stabilization and orientation system of the orbital stage in space as well as of small-size sources of energy supply (improved solar batteries, oxygen-hydrogen fuel elements, nuclear thermo-electric batteries).

The program for creating a transport spacecraft and inhabitable orbital stations pushes forward the need to develop new prospective life-support systems which include in themselves artificial atmosphere units, oxygen regeneration units, carbon dioxide elimination, water purification units, space suits and other devices.

The complexity for the realization of the program noted is not limited to the problems enumerated. The need for improving the command and measuring complexes, the development of astronaut rescue systems at all stages of flight as well as the questions of the exploitation of new rocket and space systems are usually related to this complexity.

In the future the creation of the so called space transport-tugs which will be used to transfer payloads from one geocentric orbit to another as well as for the transfer of space objects into a selenocentric orbit or a flight trajectory to the planets, is planned on the basis of the transport spacecraft. The transport spacecraft must insert the tug-spacecraft into the initial orbit.

The further prospective development of the transport spacecraft is the use of nuclear energy engines. NASA is examining the possible use in the future of a rocket unit with a nuclear rocket engine, "NERVA" for the transport spacecraft. In accordance with the calculations, a nuclear rocket engine weighing 168 tons can deliver a payload weighing 54 tons from a geocentric orbit into a selenocentric orbit.

The program of creating a transport spacecraft which can be re-used many times is a logical continuation of the idea of the further development and expansion of the possibilities of aviation flight apparatus for the purpose of reaching near-earth space and of transferring into hypersonic flight speeds.

The re-useable manned spacecraft (aircraft) will mark the appearance of space aviation.

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